

Sandia's PV Reliability Program

Sandia National Laboratories

Jennifer Granata, Rob Sorensen, Jay Johnson, Bob Kaplar, Joshua Stein, Steve Milller, Matt Marinella, Jack Flicker, Ben Yang, Colin Hamman

PHOTOVOLTAICS

Reliability Program Goals

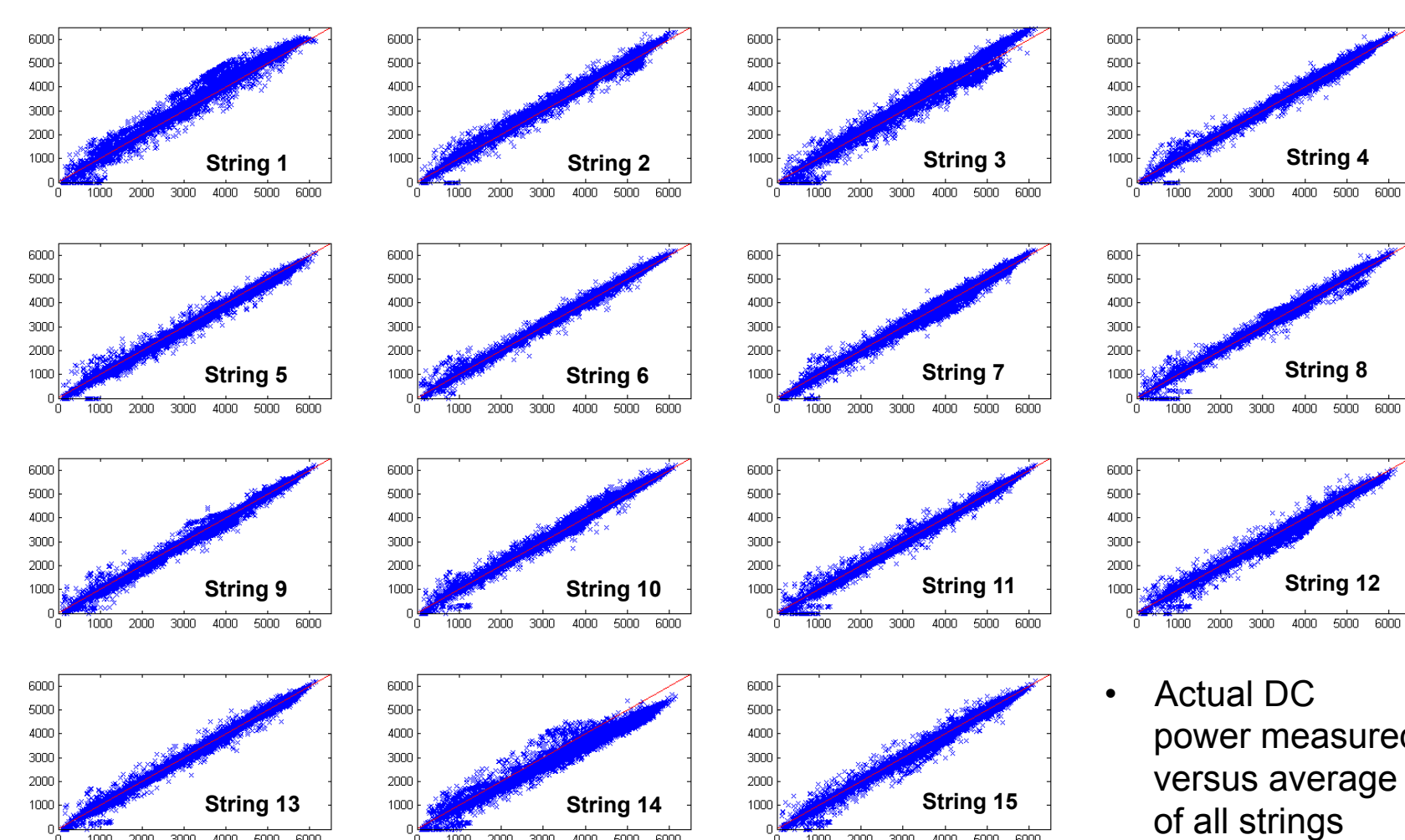
- Understand what limits reliability of PV systems
- Identify activities to increase reliability and availability
- Predict reliability with quantifiable uncertainties

Link to SunShot Goals

- Accelerate solar deployment
 - Demonstrate safe, long-lived, predictable PV systems
- Reduce the time from development to commercialization
 - Design for reliability methods and protocols
- Foster collaborations with manufacturers, integrators, installers, operators, and the finance community

Systems Testing and Analysis

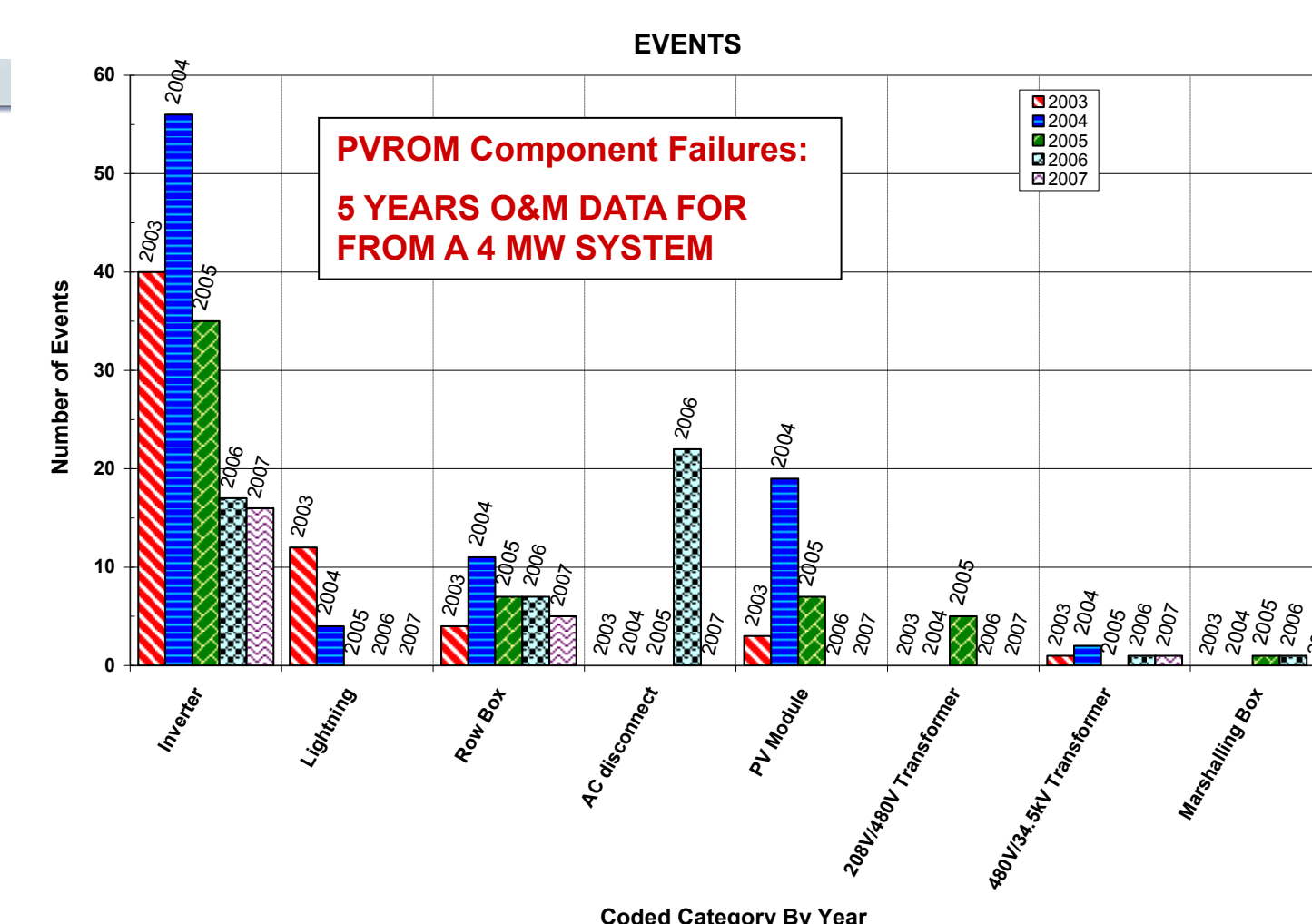
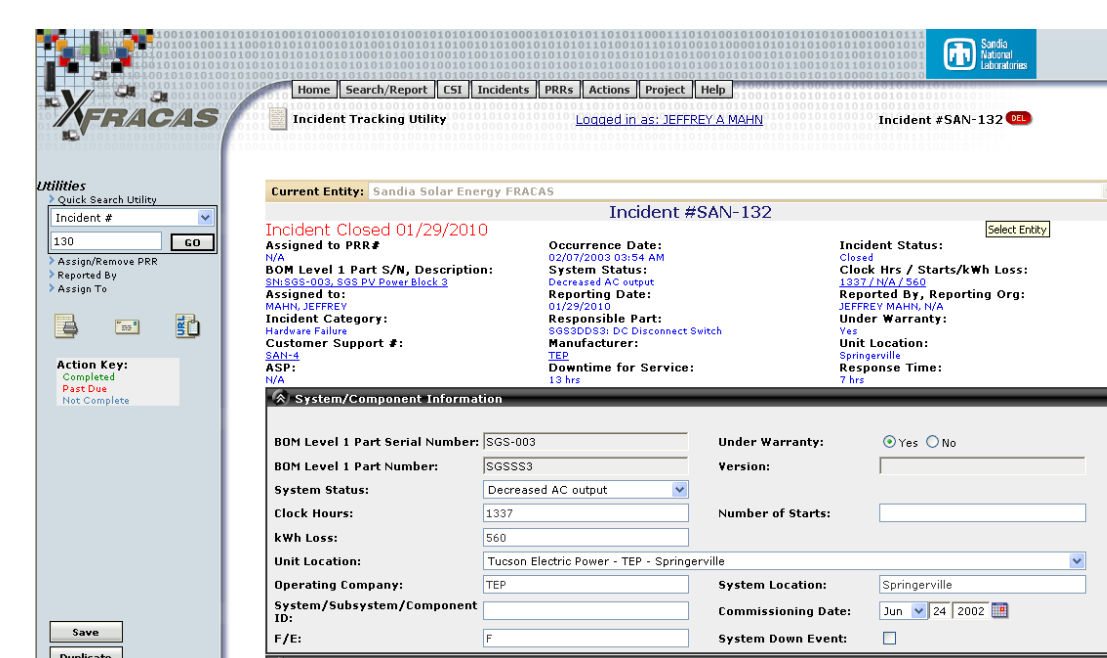
- Assess systems-level reliability
 - Small systems (1-5 kW) in multiple climates (NM, VT, FL) to measure and calculate degradation rates
 - Medium scale systems (30-300 kW) in multiple climates to identify reliability trends and issues
- Example: SunPower C7 Test System at Sandia: 100 kW low-X CPV with string-level monitoring



- Actual DC power measured versus average of all strings

PV Reliability and O&M Database and Data Collection tool (PVRM)

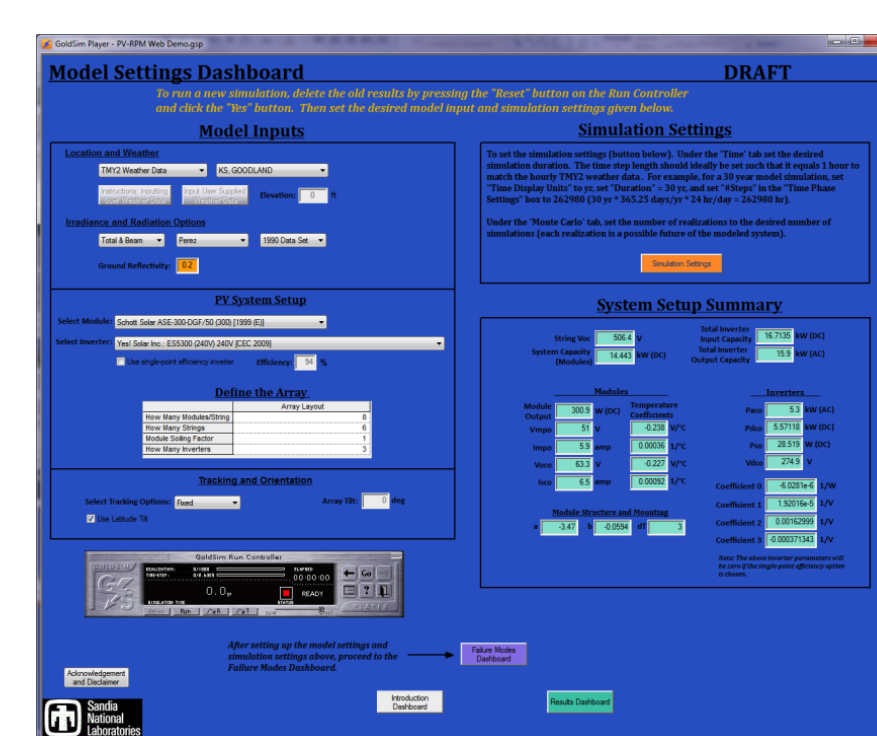
- Sandia developed a standardized O&M data collection tool based on ReliaaSoft's XFRACAS platform
- Collect system-level incident, failure, and repair data
- Identify issues and generate failure statistics
- Supplies input to performance and reliability models
- Aggregate data from multiple installations (3 current partners; goal of 10+ in FY13)



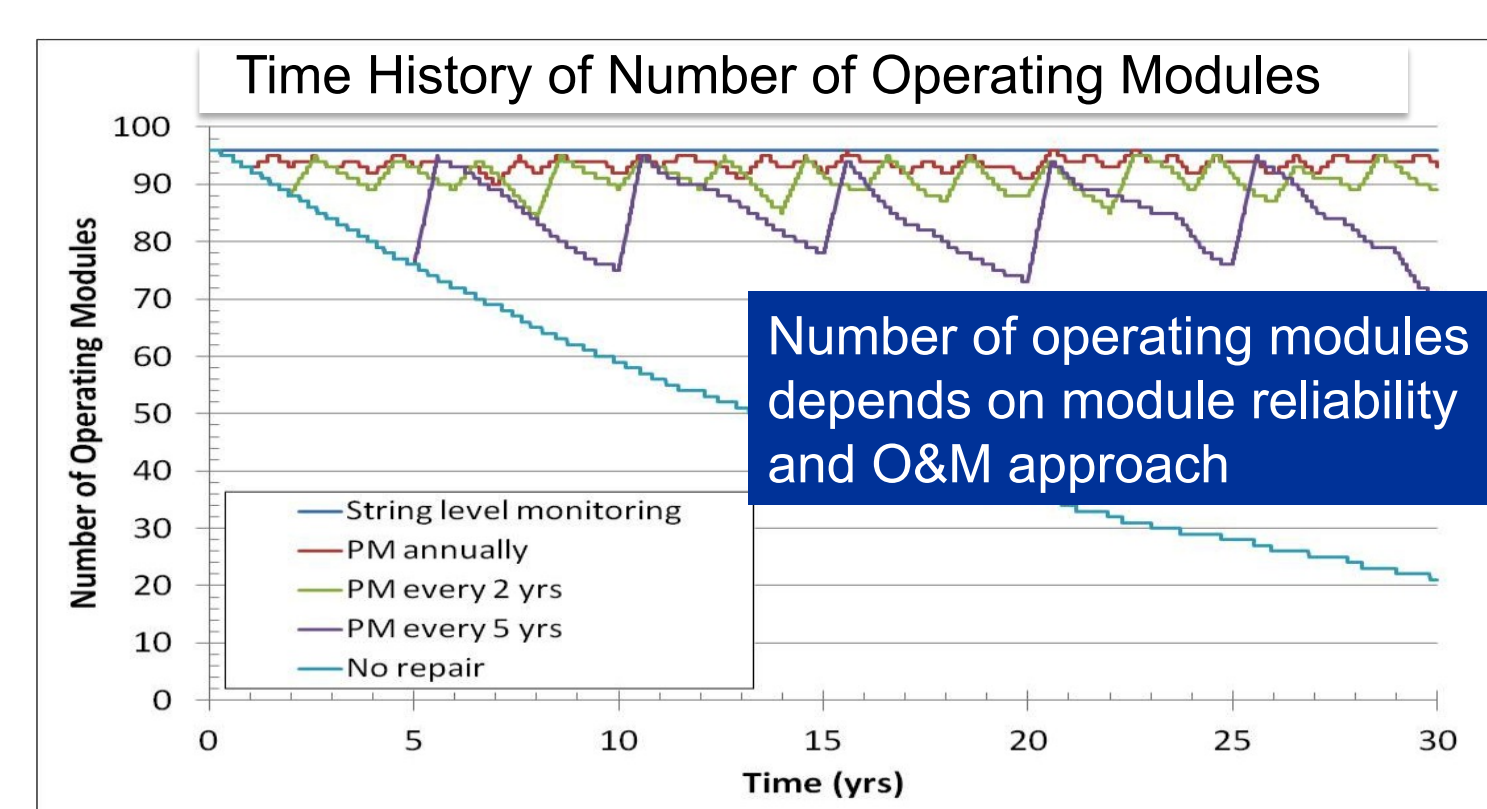
PV Reliability and Performance Model (PV-RPM)

- Sandia developed a tool to assess decisions about PV plant performance, maintenance and operations
- PV-RPM can be used to: make design decisions, choose operating strategies, evaluate uncertainties and sensitivities
- Rich analytical and visualization tool to simulate detailed PV plant operational scenarios
- All parameters can be represented as constants or stochastics (probability distributions)
- Includes a weather model, performance model, and a reliability model

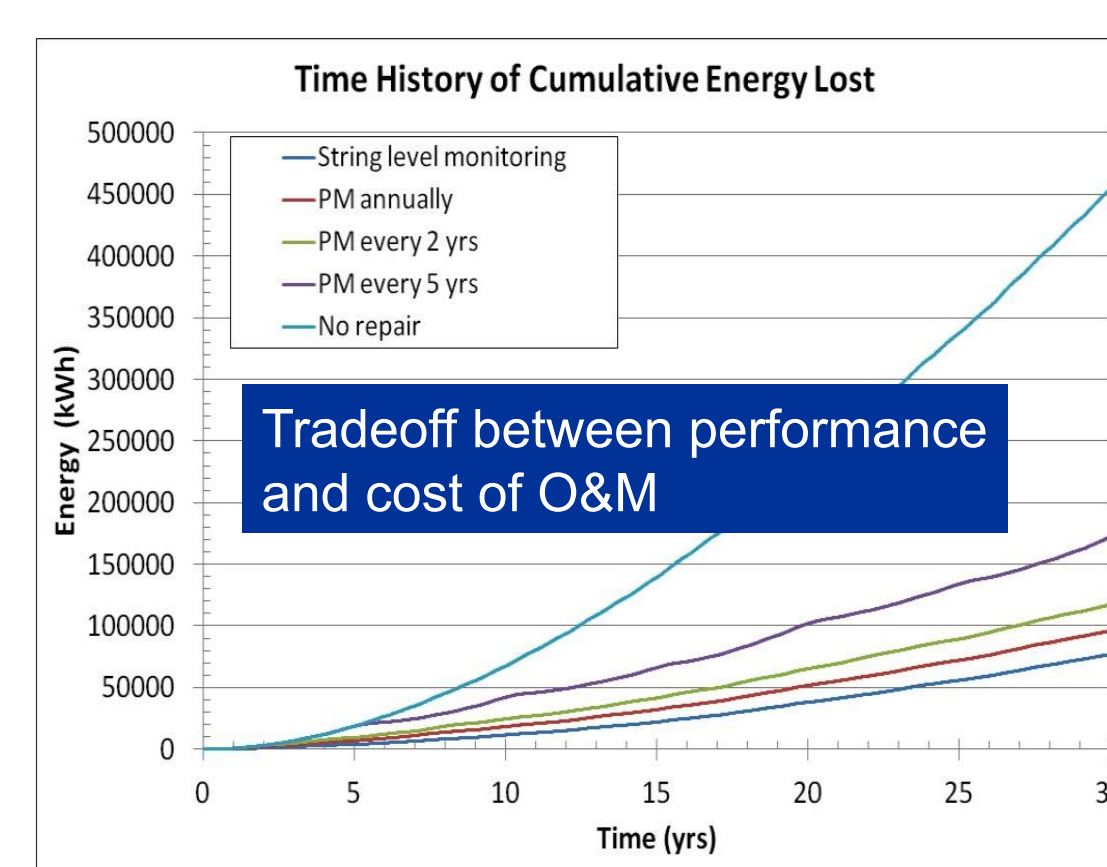
Sample output: Sensitivity studies of preventative maintenance (PM) scheduling



Inputs dashboard



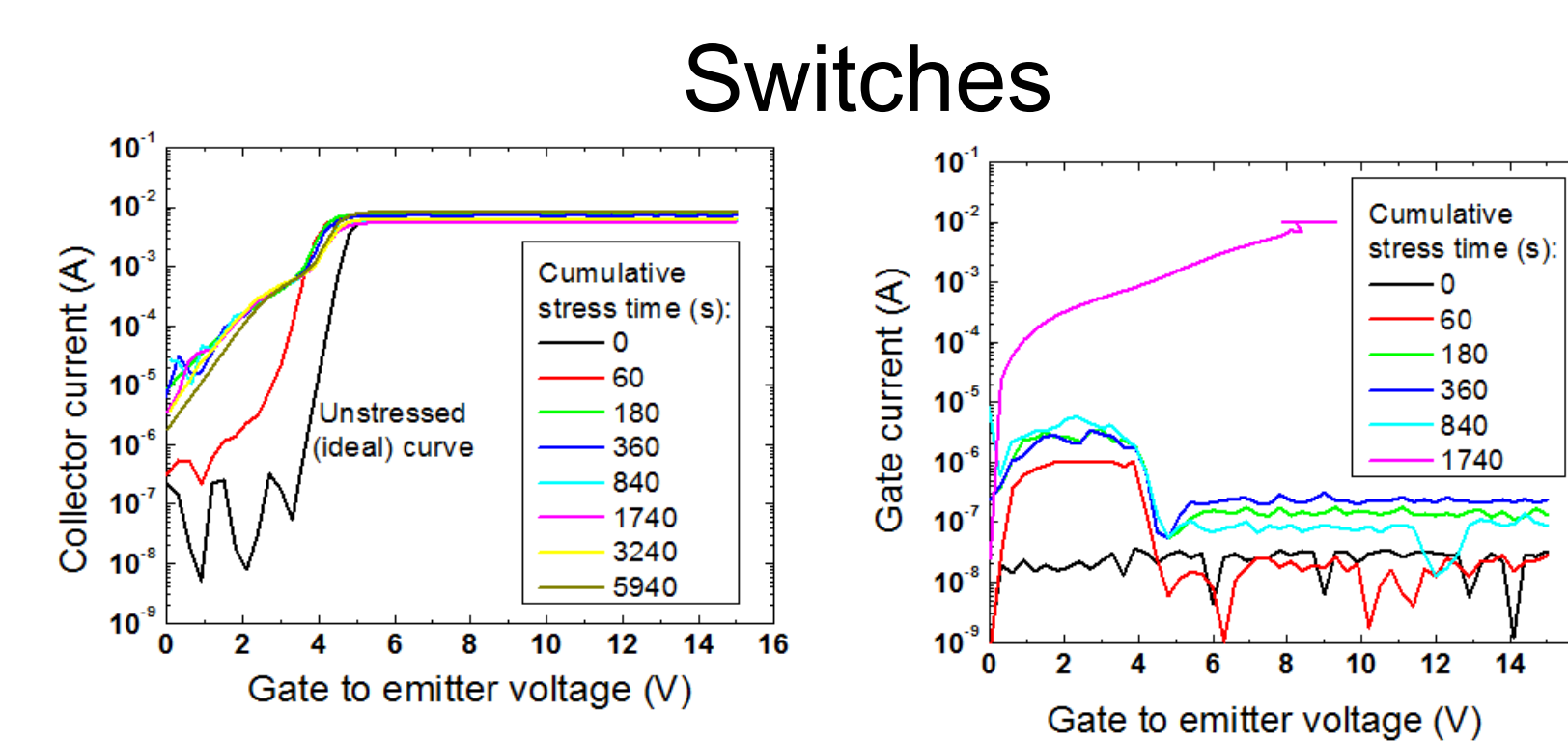
Number of operating modules depends on module reliability and O&M approach



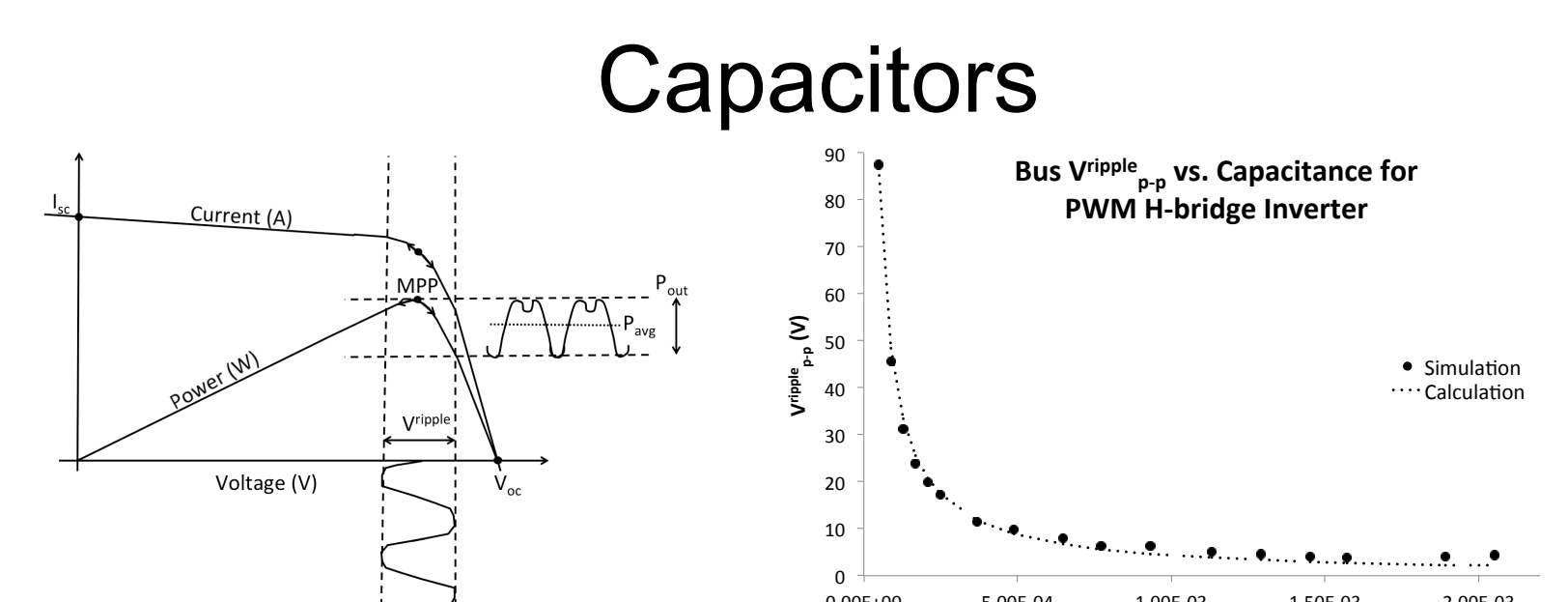
Tradeoff between performance and cost of O&M

Inverter Reliability at the Component and System Level

- Power electronics identified as critical components for inverter lifetime
- Sandia applies accelerated life testing enable inverter reliability predictions

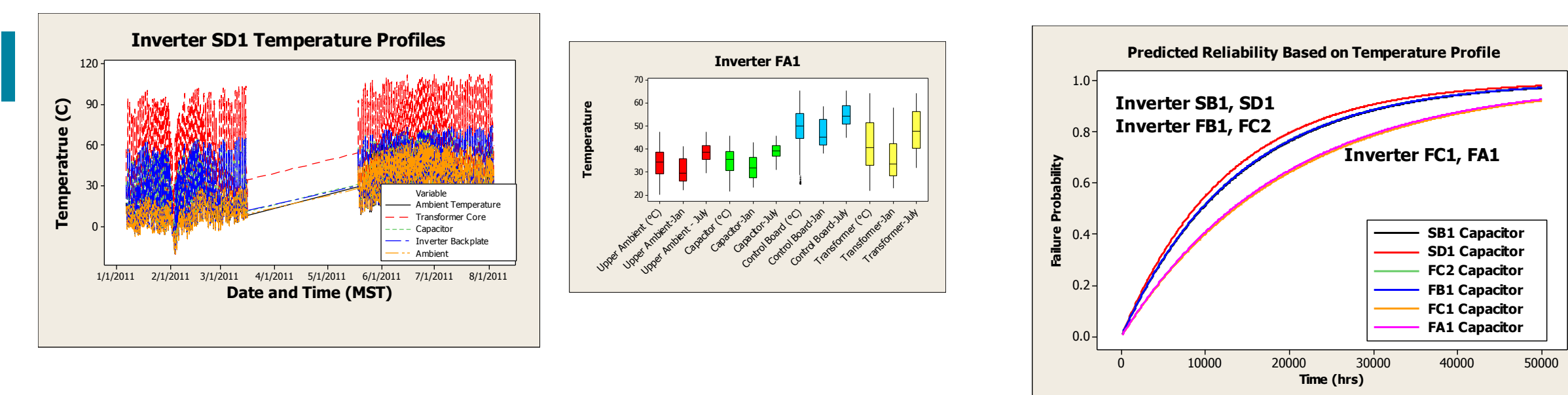


- Work focuses on electrically stressing IGBTs and measuring the change in electrical properties
 - Circuit simulations
 - Experimental testing
 - Correlation between simulations and experiment.
- Next steps: experimental testing of other transistor types, such as wide bandgap SiC switches



- Work focuses on understanding how capacitor degradation effects inverter output over time
 - Circuit simulations
 - Experimental testing of capacitors
 - Capacitor degradation and lifetime as a function of temperature and voltage stress

Real-time testing: Measure component temperatures inside working inverters

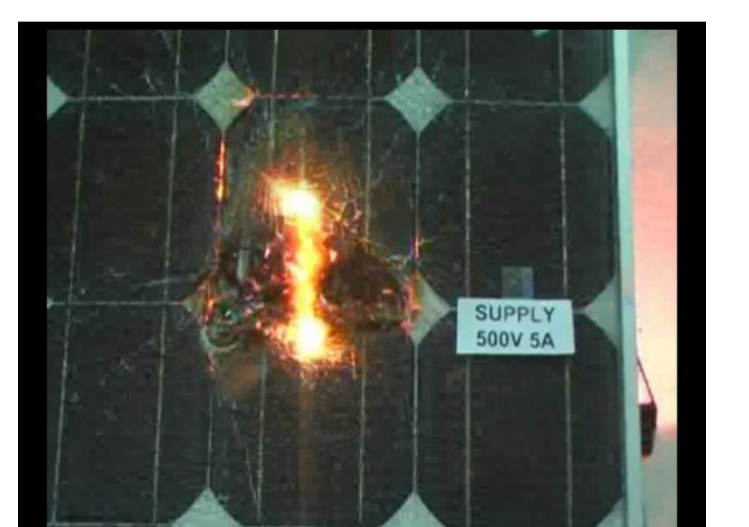
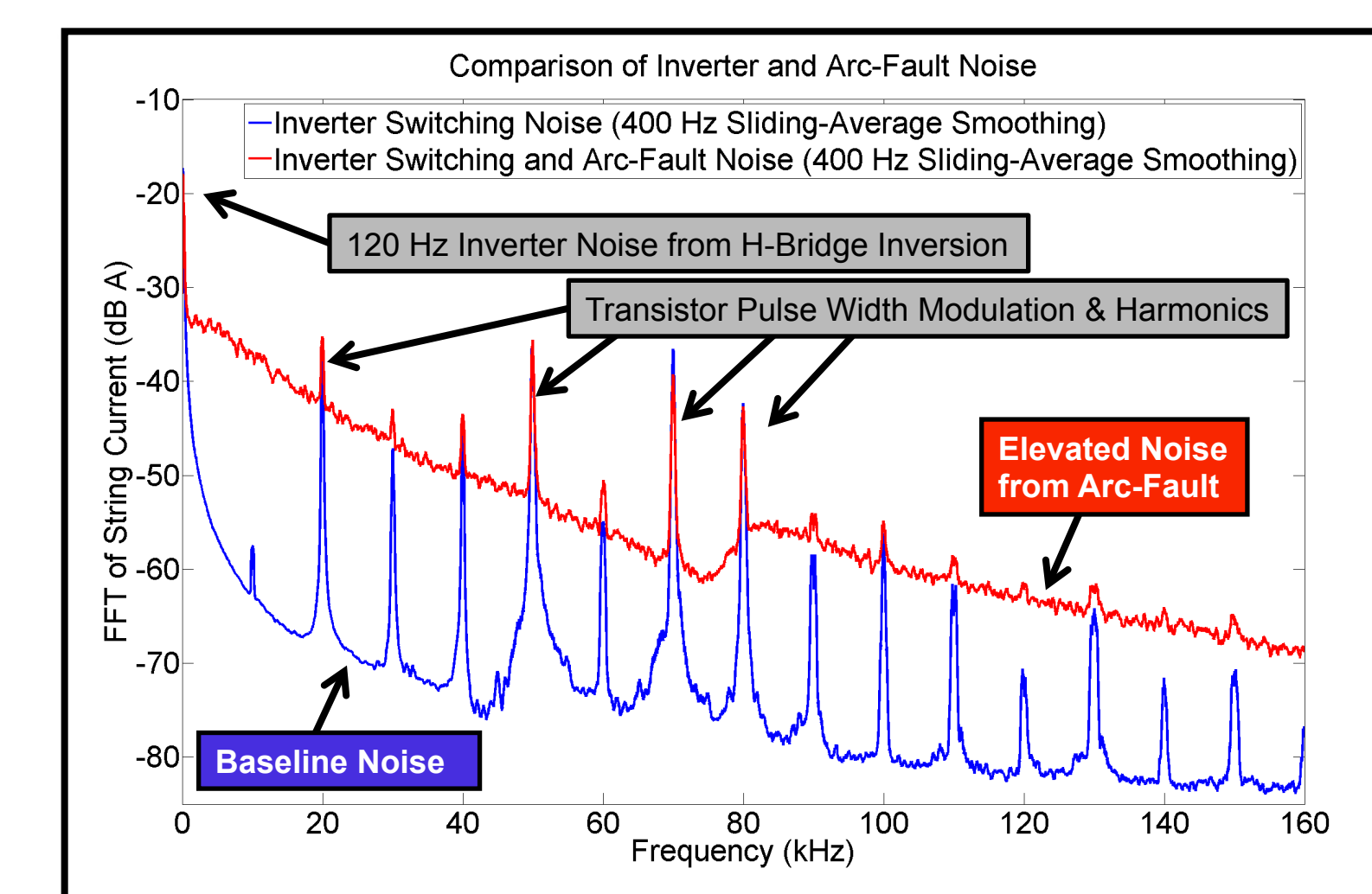


- Understand thermal profile for inverter and components
- Predict reliability: use an accumulated damage model

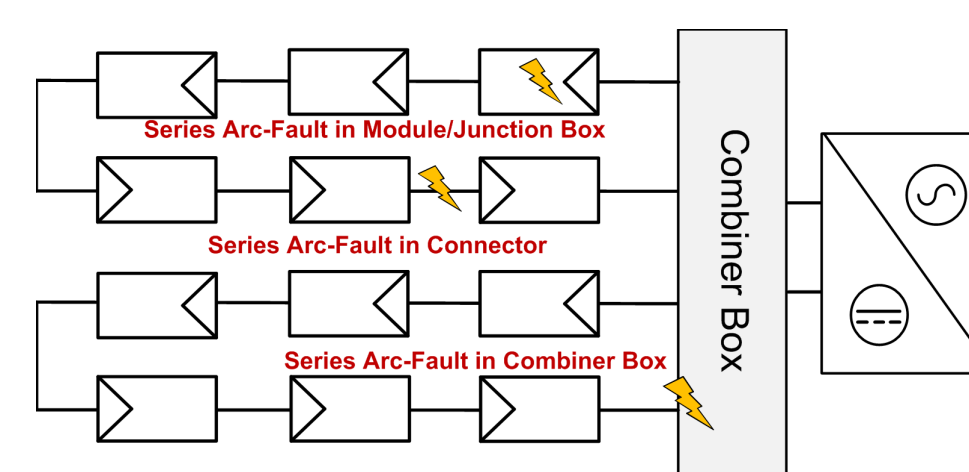
$$\varepsilon = \Delta_{T(1)} \times \lambda_{T(1)} + \Delta_{T(2)} \times \lambda_{T(2)} + \dots + \Delta_{T(n)} \times \lambda_{T(n)}$$

— Compare Inverters, location, installation

Arc-Fault Detection and Mitigation



- The 2011 National Electrical Code 690.11 requires series arc-fault protection to minimize the risk of electrical fires in PV systems.
- Sandia is actively researching arc-fault noise propagation in PV systems and working a number of companies to develop arc-fault circuit interrupters.



Gaps

- Current reliability assessments are empirical and based on historical data
- Many failure modes/mechanisms not fully understood
- Missing lab-to-field correlations and acceleration factors
- Reluctance to share data: corporate image

Future Work

- Develop validated component-level accelerated tests
- Establish PHM methodology and capability for PV systems
- Validate performance and reliability models